

# MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 56, No. 3  
W. B. No. 951

MARCH, 1928

CLOSED MAY 3, 1928  
ISSUED MAY 28, 1928

## SECOND PHASE OF STREAMFLOW EXPERIMENT AT WAGON WHEEL GAP, COLO.

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[Reprint from portions of Monthly Weather Review Supplement No. 30 (Forest and Stream-flow Experiment, Wagon Wheel Gap, Colo.)]

### HISTORY AND DESCRIPTION OF THE PROJECT

#### INTRODUCTION

Foresters generally, and nearly all others familiar with the conditions in mountainous regions, believe strongly in the protective value of forests, first, as binding the soil, covering it with humus and litter, and preventing its erosion; and, secondly, as exerting a modifying effect upon the flow of streams. The latter assumption is based primarily upon the obvious fact that the covering of spongy material upon the floor of the forest must prevent the rapid run-off of any normal rainfall, mainly by the absorption of a considerable portion of the water. Of this a certain amount is thus allowed to percolate into the deeper soil where through the medium of underground springs it maintains the even flow of streams. The retardation of snow melting in the western mountains of the United States is another service that forests are believed to perform in the regulation of streamflow and the protection of watersheds, and one which no other form of vegetation could accomplish as well. Thus, in a number of ways, it has been assumed that forests reduce the magnitude of ordinary seasonal floods, tend to maintain stream flow in dry weather, and, perhaps most important of all, prevent erosion of the land which they occupy or adjoin, and thereby reduce the amount of silt carried by streams, and lessen the damage done by flood waters to fertile fields.

The present paper does not attempt to prove or disprove these assumptions, but simply to state them as beliefs which require experimental proof. Present-day needs call for experimental proof of every belief and where great economic values are involved—for quantitative determinations. It is not enough to know *whether* forests influence stream flow; it is necessary to know how much, at what seasons, and under what conditions of climate, soil, and topography, and the variations between different kinds of forest, as well.

At the time of beginning the Wagon Wheel Gap project only one other serious attempt was being made to measure the influence of forests upon stream flow, precisely, and over a long period. The results of this study, comprising 15 years of observation near Ennental, Switzerland, became available in 1919 in an exhaustive report by Dr. Engler.<sup>1</sup> This is perhaps the most authoritative statement on the subject ever published. Yet even here the results are largely qualitative, and the conclusions open to some question, for the simple reason that experimental conditions were not fully attained by first establishing stream flow relationships under similar conditions of cover. The two watersheds on which Engler's work was based, one 97 per cent forested and

the other 35 per cent forested—the remainder being in pasture, meadow, and field—were taken in their natural conditions, and comparisons of stream flow have been made only under these conditions.

There is some suggestion that the nonforested character of the one watershed may have been due in part to shallow soil and numerous rock outcrops not favorable to trees, as well as to the treatment it had received. Moreover, up to 1919, no effort was made to measure stream flow during three or four months of the winter, the total amounts of discharge being, therefore, left in doubt in this Swiss study.

The Forest Service began in 1909, with the selection of a site on the Rio Grande National Forest, near Wagon Wheel Gap, Colo., what was to be a very complete study of the effects of forest cover on stream flow and erosion under the conditions of the central Rocky Mountains. The plan, broadly stated, was to use two contiguous watersheds,<sup>2</sup> similar in topography and forest cover; to observe carefully for a term of years meteorological conditions and stream flow under these similar conditions of forest cover; then to denude one of the watersheds of its timber and to continue the measurements as before, until the effects of the forest destruction upon the time and amount of stream flow, the amount of the erosion, and the quantity of silt carried by the streams had been determined. This plan had been executed, and the experiment was terminated by mutual agreement on October 1, 1926.

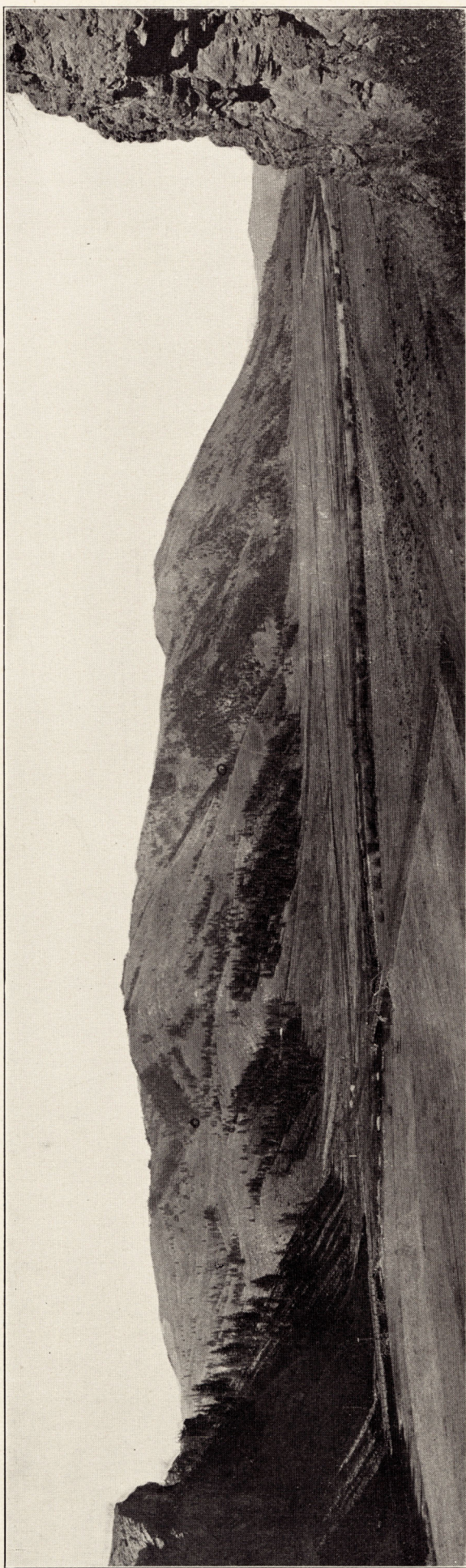
Because the plan of study contemplated by the Forest Service called for the services of men skilled in meteorological observations as well as the use of considerable instrumental equipment, the cooperation of the Weather Bureau was solicited and, on approval of the Secretary of Agriculture, the two services began on June 1, 1910, the active work of getting material and equipment on the ground. The building of cabins for living and office quarters, the installation of the meteorological instruments, and the construction of two dams occupied the time up to October 22, 1910, when the first meteorological observations were made. Rectangular weirs installed in the beginning did not prove satisfactory and it was not until the following July that satisfactory triangular weirs were installed.

By June 30, 1919, when eight years' continuous stream-flow measurements and nearly nine years' meteorological observations has been obtained, it was concluded that the first stage of the experiment had been adequately developed; it was therefore agreed that one of the watersheds (B) should be denuded at once, except that a strip of timber not to exceed 25 feet in width should be left on each side of the stream for a single season, or until the autumn of 1920. This program was carried out as

<sup>1</sup> Engler, Arnold. Experiments Showing the Effect of Forests on the Height of Streams. *Mitteilungen der Schweizerischen Centralanstalt für das Forstliche Versuchswesen*. XII, 1919, Zurich.

<sup>2</sup> Throughout this discussion, and in all of the records the convenient and perhaps more popular word "watershed" is used to denote a drainage basin.





FRONTISPIECE.—View of watersheds A and B, Wagon Wheel Gap, Rio Grande in foreground. (Heavy circles show location of Dams A and B)

Photos. 90898-9-900, F. S., 1910, A. G. Varela





It should be evident from the rocky character of the soil of the watershed, and still more from the layer of rock fragments covering its surface, that the soil is permeable and receptive to water—a fact of the utmost importance when considering the results of this experiment and their application under other conditions. Whether this ability to absorb water is the primary factor explaining the steady flow of the streams (it is evident from certain calculations that the watersheds can not drain dry in less than 6 or possibly 12 months), or whether the rather remarkable water-holding capacity of the slopes denotes a soil of more retentive character next to the bedrock and in its crevices is perhaps unimportant. It is highly probable, however, that clay in crevices causes a very slow draining out of the water which penetrates most deeply. Such a condition was observed where the dams were constructed.

## SUMMARY AND CONCLUSIONS

### SUMMARY

#### CONDITIONS OF EXPERIMENT

1. This experiment deals with streamflow from two mountain watersheds of about 200 acres each, located on the drainage of the Rio Grande in southern Colorado. Their elevations are between 9,000 and 11,000 feet, whereas the areas in Colorado producing living streams extend mainly from 8,000 to the highest peaks, some of which are 14,000 feet in altitude. These watersheds therefore should be average or only slightly below in water-yielding capacity.

2. The geological formation of the locality, a quartz-lattice flow of great uniformity over the two watersheds, and the coarse, sandy soil derived therefrom, containing and covered by many small rock fragments, were conducive to a very high degree of absorption of rain and snow water. Hence there appeared very little surface run-off at any stage of the experiment, and the quantities of soil eroded were of extremely small magnitude. Only the coarse granitic soils occurring in portions of Colorado would be likely to show greater absorptive and storage capacities than the soils of these watersheds; the igneous formations, in general, produce somewhat finer soils; the sedimentaries of the high plateaus of southern Colorado and of the foothills of both the eastern and western slopes might be expected to absorb water less readily and to be much more erodable. It is, therefore, evident that a very conservative basis was selected for demonstrating the possible effects of forest removal on streamflow and erosion, particularly the effects of soil disturbance and change.

3. The forest cover of both watersheds, though far lighter than the undisturbed stands at similar elevations in the Rocky Mountain region, was fairly typical of the region as a whole, it having been heavily visited by fires. The original forest was mainly Douglas fir at the lower and Engelmann spruce at the higher elevations. These areas were burned over about 35 years ago, watershed B (the one which was denuded in the experiment) having been burned somewhat more extensively than A. The burned areas had come back largely to a scrubby growth of aspen, which, while forming dense thickets and thereby protecting the soil adequately, is obviously less effective than conifers as a shade to retard the melting of snow. Consequently any effect on snow melting from the removal of such a cover would be moderate in comparison with the effect of removing a complete canopy formed by evergreens.

4. Stream flow and the meteorological conditions of both watersheds were recorded continuously from late in 1910 until October 1, 1926, triangular-notch weirs and Friez automatic water-stage recorders being employed to assure the greatest possible precision in the measurements of streamflow.

October 1 was taken as the starting point for the streamflow year, and the data both of stream flow and precipitation have been summarized accordingly from October 1, 1911, for the eight years before denudation of B and the seven years subsequent thereto.

So far as known, this experiment differs from any other experiment of a like nature ever made in that streamflow measurements were maintained throughout the extreme low temperature of winter,  $-25^{\circ}\text{F.}$  ( $-31.7^{\circ}\text{C.}$ ).

5. The denudation of B watershed was started in July, 1919, but was not completed until late in 1920. About one-fifth of the total ground area was burned over and sufficiently heated to prevent the immediate sprouting of the aspen from rootstocks. Elsewhere the vegetation and soil were little affected and a feeble growth of aspen started almost immediately over most of the area. At the end of 1926 this had reached an average height of 4 feet, but conifers were, of course, lacking.

#### GENERAL CLIMATIC CONDITIONS

6. The outstanding characteristics of climate and streamflow established during the first eight years of the experiment were as follows:

(a) A mean annual temperature of about  $34^{\circ}\text{F.}$

(b) A mean annual precipitation of about 21 inches.

(c) Precipitation about half snow and half rain. Except on the south slopes there is practically no melting throughout the winter until after March 1. About one-half of the total annual precipitation is released during the melting period, which ordinarily does not end until about June 1. More than 55 per cent of the total annual run-off appears during the flood stage, the average time of which is from March 30 to June 30, under the arbitrary limitations set for it.

(d) Owing to differences in conformation and underground conditions of the two watersheds, B is a more effective storage reservoir than A, and consequently its stream neither reaches a peak of flow quite so soon as that of A, nor drains out the excess from the spring flood and storage so soon. The lag during the rise of the flood seems to be further accentuated by the fact that the orientation and other features of B do not permit the early season insolation to be as effective as on A in melting the snow, especially near the stream channel. The importance of this is that the constant lag of B makes difficult the direct comparison of the height of the two streams at any given time. It is apparent from the ratios of run-off to current precipitation that B carries over from one year to the next a greater quantity of ground water than is carried over by A.

(e) As much as 42 per cent of the current year's precipitation may appear as run-off when the precipitation is sufficient and snow-melting conditions are favorable and as little as 17 per cent in years of low precipitation and unfavorable climatic conditions.

The losses of water by evaporation remain fairly constant at about 15 inches per annum, although by reason of the hold-over water from one year to another an accurate determination of this point is impracticable.

#### CLIMATIC COMPARISON OF TWO PERIODS

7. The mean annual temperature of watershed A as deduced from hourly readings for both periods was